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Late surgical conversion after failed endovascular aortic repair: Our single-institutional experience

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ABSTRACT

Objectives: In this study, we report our single-center experience with late surgical conversion (SC) after endovascular aneurysm repair (EVAR) and risk factors for reintervention.

Patients and methods: Between January 2007 and December 2017, a total of 98 patients (94 males, 4 females; mean age: 69.1±8.6 years; range, 35 to 86 years) who underwent infrarenal EVAR were retrospectively analyzed. During the study period, additional eight patients who underwent EVAR at an external center were referred to our center. Overall, nine patients underwent late SC. In the late SC group, stent grafts used for EVAR were Endurant™ (n=5), Talent™ (n=2), Powerlink™, and Anaconda™ (n=1).

Results: The mean time from initial EVAR to open conversion was 45.3±35.4 months. Four (44.4%) patients presented with more than one different concomitant indications. The most frequent reason for the late SC was type 3 endoleak (n=5, 55.5%). Late SC was performed electively in five (55.5%) patients. Partial stent graft removal was performed in three (33.3%), complete removal in three (33.3%), and complete preservation of the stent graft in three (33.3%) patients. Among 98 patients, the mean aneurysm diameter was significantly higher in those with late complication and undergoing second EVAR (p=0.001). The cut-off value for second EVAR was ≥66 mm with a sensitivity of 88.89% and specificity of 71.91% (p=0.001).

Conclusion: The surveillance program after EVAR is of utmost importance to ensure that patients do not need urgent conversion, particularly in patients with an initial aneurysm diameter of ≥66 mm.

Keywords: Abdominal aorta aneurysm, complication, endovascular aneurysm repair, late surgical conversion.

Endovascular aneurysm repair (EVAR) has revolutionized the management of infrarenal abdominal aortic aneurysms (AAAs), since the first successful intervention two decades ago.[1] Advances in endovascular stent technology, increasing experience and technical skills have resulted in EVAR becoming the treatment of choice for more than half of patients in many referral centers.[2]

Despite the benefits of EVAR compared to the open surgery, such as significantly lower short-term mortality, shorter hospitalization, more rapid recovery and less pain, the long-term durability of EVAR still remains as a concern. It is also associated with increased rates of reintervention to treat endoleak, graft rupture, stent fractures, graft thrombosis and infection with longer follow-up time.[3] The majority of these complications can be successfully managed with endovascular interventions; however surgical conversion (SC) is still required in 0 to 9% of cases as a last resort in the management of complications refractory to endovascular intervention.[4,5] Surgical conversion after EVAR is technically more challenging compared to primary open repair and is associated with remarkably high mortality rates in emergency patients, ranging between 20 and 40%.[6] However, mortality rates in elective SCs are more reasonable, similar to primary open repair.[7]

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In the present study, we report our single-center experience with late SCs after EVAR, to evaluate the current indications, surgical strategy, and clinical course for conversion, and to identify possible risk factors for reintervention.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Dr. Siyami Ersek Chest Heart and Vascular Surgery Training and Research Hospital, Department of Cardiovascular Surgery between January 2007 and December 2017. Data of patients who underwent infrarenal EVAR and late SC after previous EVAR during the study period were screened. Data of patients who underwent late SC at our center after an index EVAR procedure performed at an external institution were also reviewed. Finally, a total of 98 patients (94 males, 4 females; mean age: 69.1±8.6 years; range, 35 to 86 years) who underwent infrarenal EVAR were included. During the study period, additional eight patients who underwent EVAR at an external center due to sac enlargement or graft thrombosis after failed EVAR were referred to our center. Overall, nine patients underwent late SC. Patients' demographic, anatomic, operative, and postoperative data were retrieved from the hospital database. Missing surveillance data were completed using the dataset records for the Republic of Türkiye, General Directorate of Civil Registration and Nationality.

The late SC was defined as a surgical reintervention performed at least 30 days after the initial EVAR. The 30-day cut-off was determined to exclude the cases, if the conversion was performed on time or within first 30 days of the initial EVAR. The EVAR device brand, pre-EVAR aneurysm diameter, EVAR configuration (bifurcated, aortouniiliac), indication for SC, interval between initial EVAR and late SC, intraoperative data, length of hospital and intensive care unit (ICU) stay, postoperative complications, operative mortality, 30-day mortality, and long-term mortality were noted. Intraoperative data included surgical approach (transperitoneal or retroperitoneal), the SC technique (stent graft removal; complete/partial or not), position and duration of aortic cross-clamping, type of reconstruction, estimated blood loss, and operative time. The physical status of all patients was evaluated preoperatively using the American Society of Anesthesiologists (ASA) score.

All patients underwent ultrasound imaging and computed tomography angiography (CTA) surveillance at one, six, and 12 months and, then, annually as the post-EVAR follow-up protocol at our institution. The late SCs were performed either in the elective and emergency setting. Emergency SCs were performed for patients with painful or ruptured aneurysms. In our clinical practice, SC was performed as a last resort for the cases in whom endovascular reintervention was not feasible. The patients with rupture in the emergency setting preferably underwent late SC. Preoperative CTA scan was performed in all patients undergoing late SC.

Statistical analysis

Statistical analysis was performed using the Number Cruncher Statistical System (NCSS) version 2007 software (NCSS LLC, Kaysville, UT, USA). Continuous variables were presented in mean ± standard deviation (SD), while categorical variables were presented in number and frequency. The Mann-Whitney U test was used to compare the differences between two independent groups, when the dependent variable was ordinal or continuous, but not normally distributed. The Student t-test was used for groups with normal distribution. The Pearson correlation analysis was used to examine the relationships between variables. The Pearson chi-square test, Fisher-Freeman-Halton test, and Fisher exact test were used to compare the qualitative data. The receiver operating characteristic (ROC) curve was used to obtain a cut-off value to predict the need for a second intervention. A p value of <0.05 was considered statistically significant with 95% confidence interval (CI).

RESULTS

Demographic and preoperative characteristics of patients who underwent late SC are summarized in Table 1.

Aneurysm characteristics

The mean initial AAA diameter of the patients was 62.1±8.6 mm. The mean aneurysm diameter was significantly higher in patients undergoing second EVAR (p=0.001) (Table 2). Therefore, a cut-off value regarding the initial diameter of the aneurysm sac was determined to predict the need for a second intervention or subsequent SC. The ROC curve analysis and diagnostic scan tests are shown in

Table 1
Baseline characteristics of patients (n=9)

	n	%	Mean±SD	Range
Age (year)			69.1±8.8	59-85
Sex				
Male	8			
Female	1			
Late SC				
Emergency	4	44.4		
Elective	5	55.5		
ASA class				
III	6	66.6		
IV	3	33.3		
Indications for late SC				
Endoleak type 1a	2	22.2		
Endoleak type 3	5	55.5		
Rupture	3	33.3		
Graft thrombosis	2	22.2		
Migration	3	33.3		

SD: Standard deviation; SC: Surgical conversion; ASA: American Society of Anesthesiologists.

Table 2
Comparisons of aneurysm diameters

		Aneurysm diameter			
	n	Mean±SD	Median	Min-Max	*p*
Late complication					
No	69	60.87±7.68	60	45-81	t:-2.105
Yes	29	65.31±10.21	68	45-87	0.041*†
Second EVAR					
No	89	61.02±7.95	60	45-81	Z:-3.896
Yes	9	73.67±7.66	71	63-87	0.001**‡
Surgical conversion					
No	97	61.93±8.36	61	45-82	-
Yes	1	87.00±0	87	87-87	-

EVAR: Endovascular aneurysm repair; SD: Standard deviation; † Student-t test; ‡ Mann-Whitney U test; * p<0.05; ** p<0.01.

Table 3
Diagnostic scan tests for aneurysm diameter and ROC curve results

	Diagnostic scan					ROC Curve		
	Cut-off	Sensitivity	Specificity	PPV	NPV	Area	95% CI	*p*
Late complication	≥66	55.17	75.36	48.48	80.00	0.645	0.514-0.775	0.024*
Second EVAR	≥66	88.89	71.91	24.24	98.46	0.895	0.813-0.976	0.001**

ROC: Receiver operating characteristics; EVAR: Endovascular aneurysm repair; PPV: Positive predictive value; NPV: Negative predictive value; * p<0.05; ** p<0.01.

Table 3. The cut-off value for the second EVAR was ≥66 mm with a sensitivity of 88.89%, specificity of 71.91%, positive predictive value (PPV) of 24.24%, and negative predictive value (NPV) of 98.246% (p=0.001). In the ROC analysis, the area under the curve (AUC) was determined as 89.5% (Figure 1).

Initial endovascular intervention characteristics in late SC group

All initial EVARs were performed electively due to AAAs. The mean aneurysm diameter before EVAR was 76±7.4 mm. The mean time from initial EVAR to open conversion was 45.3±35.4 months. Initially implanted endovascular grafts that required conversion included Endurant™ (Medtronic Inc., CA, USA) in five (55.5%), Talent™ (Medtronic, CA, USA) in two (22.2%), Anaconda™ (TERUMO Corp., MI, USA) in one (11.1%), and Powerlink™ (Endologix LLC, CA, USA) in one (11.1%) patient. Endovascular reinterventions were attempted in four (44.4%) patients as a salvage procedure before subsequent conversion.

Indications for late SCs

Four (44.4%) patients had more than one different indication for the late SC. The most frequent reason was type 3 endoleak with aneurysm sac expansion (n=5, 55.5%), followed by graft migration with sac expansion (n=3, 33.3%) and rupture (n=3, 33.3%). No endoleak was observed in three patients.

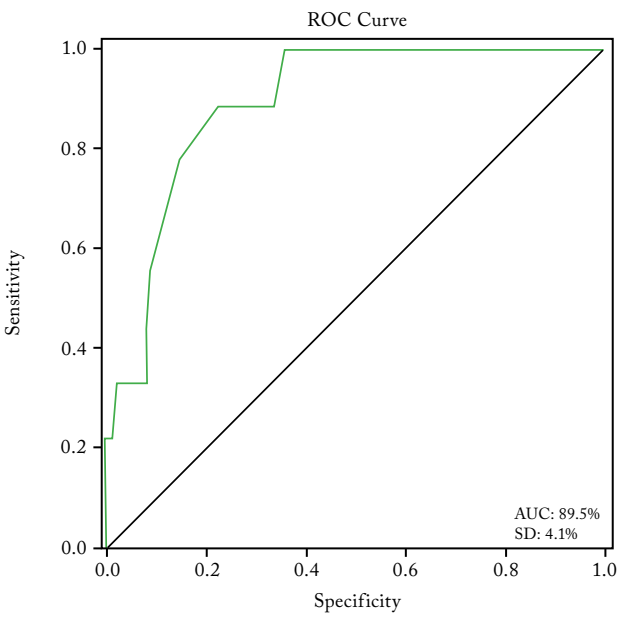

Figure 1. A ROC curve analysis for a cut-off value regarding the initial diameter of the aneurysm sac was determined to predict the need for a second intervention or subsequent surgical conversion.

ROC: Receiver operating characteristics; AUC: Area under the curve.

Late SC was performed electively in five (55.5%) patients and emergent surgery was applied in the remaining four patients. The emergency group included three patients with rupture and one patient with painful sac enlargement and graft migration.

In the elective group, indications for the late SCs were proximal type 1 endoleak (n=2), type 3 endoleak (n=2), graft migration (n=1), and graft thrombosis (n=2); one of them presented with main body occlusion and the other with left iliac limb occlusion. The details for the late SC for each individual case are summarized in Table 4.

Surgical procedure

The surgical approach included a midline transperitoneal approach in seven (77.7%), patients and extra-anatomic axillofemoral bypass (n=1, 11.1%) and cross-femoral bypass (n=1, 11.1%). Operative details are shown in Table 5.

The abdominal aorta was cross-clamped suprarenally in four (44.4%) patients and infrarenally in two (22.2%) patients, and the thoracic aorta was cross-clamped to provide emergency proximal aortic control in one hemodynamically unstable patient (11.1%) who presented with a ruptured aneurysm.

The aortic cross-clamp was gradually shifted distally in all patients who underwent suprarenal aortic cross-clamping during aortic reconstruction to reduce visceral and renal ischemic time. The proximal aortic cross-clamping was not performed in two cases undergoing extra-anatomic bypass grafting. The mean duration of the aortic cross-clamping was 24.5±11.1 min. Distal arterial control was achieved by cross-clamping of iliac arteries below the stent graft in five patients and at the stent graft level in two patients in whom further iliac exposure was not feasible.

After the aneurysm sac was opened, back-bleeding lumbar arteries were oversewn. In three (33.3%) patients, the proximal and distal end of the stent graft were well incorporated into the aortic wall. Partial stent graft removal was performed to reduce the risk of intraoperative injury to the aortic wall and to reduce aortic cross-clamping level, as well as the procedure time as previously described in detail

Table 4
Details for late SC after EVAR

Patient	Age (year)	AAA (pre-EVAR) diameter (mm)	Type of the stent graft	Indication for conversion	Emergency Status	Interval to conversion (month)	Explantation of stent graft	Operative details	Complications
1	70	72	Endurant	Endoleak type 3/ migraton/ rupture	Emergency	60	Partial	Aortic reconstruction with remnant stent grafts, Aorto-biliac bypass using bifurcated Dacron graft	The patient undergoing SC was hemodynamically unstable on admission, and died during operation
2	74	82	Talent	Rupture	Emergency	60	Complete	Aorto-biliac bypass using bifurcated Dacron graft	The patient presenting with rupture died due to acute renal failure and pulmonary complications in ICU
3	60	65	Anaconda	Graft thrombosis	Elective	5	Total preservation	Axillobifemoral bypass	None
4	60	68	Endurant	Endoleak type 1a/type 3	Emergency	62	Complete	Aorto-biliac bypass using bifurcated Dacron graft	Required temporary renal dialysis and reoperation for abdominal wound dehiscence
5	59	80	Endurat	Endoleak type 3/ migration	Elective	12	Partial	Aortic reconstruction with remnant stent grafts, Aorto-bifemoral bypass using bifurcated Dacron graft	None
6	65	68	Powerlink	Graft thrombosis	Elective	24	Total preservation	Cross-femoral bypass	None
7	81	87	Edurant	Endoleak 1a	Elective	5	Complete	Aorto-biliac bypass using bifurcated Dacron graft	None
8	68	78	Talent	Endoleak type 3/migration	Elective	60	Partial	Aortic reconstruction with remnant stent grafts, Aorto-biliac bypass using bifurcated Dacron graft	None
9	85	84	Endurant	Endoleak type 3/rupture	Emergency	120	Total preservation	Treated by nonabsorbable mass sutures with three pairs of PTFE felt pledgets	None

SC: Surgical conversion; EVAR: Endovascular aneurysm repair; AAA: Abdominal aortic aneurysm; ICU: Intensive care unit; PTFE: Polytetrafluoroethylene.

Table 5
Operative details of patients undergoing late SC (n=9)

	n	%	Mean±SD	Median	Min-Max
Interval to conversion (month)			45.33±37.61	60	5-120
Emergency status					
No	5	55.6			
Yes	4	44.4			
Approach					
Transperitoneal	7	77.8			
Extraanatomic	2	22.2			
Location of aortic cross-clamping					
None	2	22.2			
Suprarenal	4	44.4			
Infrarenal	2	22.2			
Thoracic	1	11.1			
Stent graft explantation					
Partial	3	33.3			
Total	3	33.3			
Total preservation	3	33.3			
Cross-clamping time (min)			24.57±11.99	20	0-45
Operative time (min)			214.78±47.53	220	120-284
Operative blood loss (mL)			550.00±250.00	600	150-850
Operative mortality					
No	8	88.9			
Yes	1	11.1			
Long-term mortality					
No	7	100.0			
Yes	0	0.0			
30-Day mortality					
No	7	77.8			
Yes	2	22.2			

SC: Surgical conversion; SD: Standard deviation.

elsewhere (Figure 2b).[8] However, no significant difference was found in the preference for stent graft removal options in terms of hospital mortality (Table 6). The indication for surgery in these three patients was type 3 endoleak with graft migration, and one of them also had a rupture. Aortobiiliac (n=2) and aortofemoral (n=1) bypass were performed with a bifurcated Dacron® graft as the surgical option.

Three (33.3%) patients, two of them with type 1 endoleak and one with rupture, required complete stent graft removal. In these patients, prosthetic aortic reconstruction using a bifurcated Dacron® graft was performed as aortobiliac bypass (Figure 2a).

Finally, the stents grafts were completely preserved in three of all nine patients. One of them showed rupture due to a tear in the fabric of the endovascular stent, which could be treated with three pairs of polytetrafluoroethylene (PTFE) felt pledgets and non-absorbable mass sutures. Axillobifemoral bypass was performed in one of the patients with total thrombotic occlusion of the stent graft. Patient No. 9 underwent cross-femoral bypass due to occlusion of left iliac limb of the stent graft (Figure 2c). In these three patients, complete preservation of the stent graft was achieved, reducing the risk of possible SC.

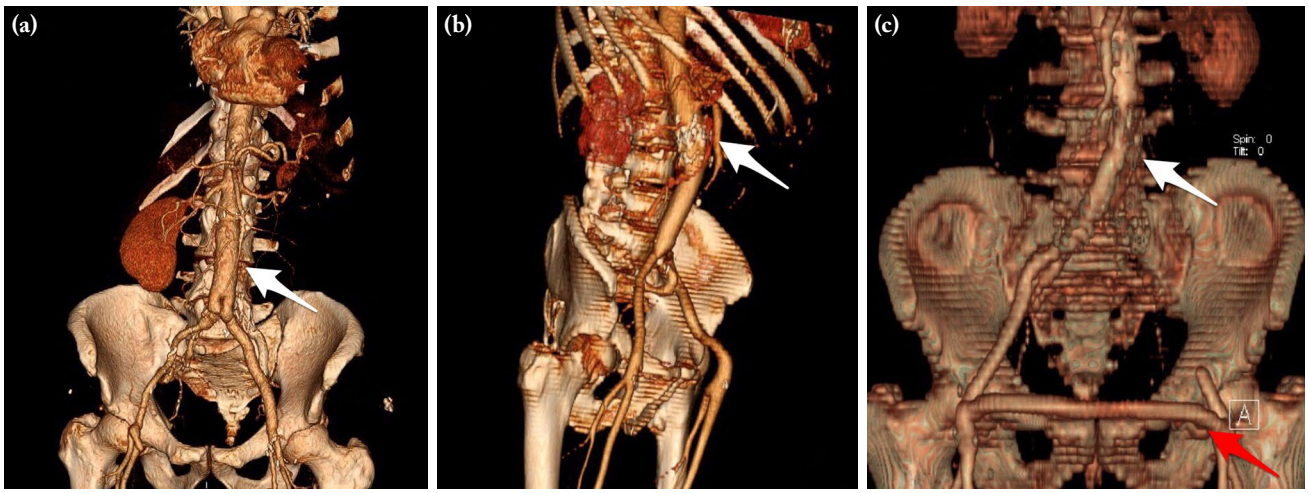

Figure 2. Three-dimensional computed tomographic angiography showed different techniques in surgical conversion after EVAR; **(a)** aortobiiliac bypass graft after total endograft explantation; **(b)** bilateral aortofemoral bypass after partial endograft explantation; **(c)** cross-femoral bypass (red arrow) with total endograft preservation in a patient with left iliac limb occlusion of endograft (white arrow).

EVAR: Endovascular aneurysm repair.

Table 6
Mortality in patients undergoing late SC (n=9)

	30-Day mortality				
	No		Yes		
	n	%	n	%	*p*
Emergency status					
No	5	100	0	0	3.214†
Yes	2	50	2	50	0.167*
Stent graft explantation					
Partial	2	66.7	1	33.3	1.509†
Total	2	66.7	1	33.3	1.000*
Total preservation	3	100	0	0	

SC: Surgical conversion; † Chi-squared test; * Fisher exact test.

Overall, partial stent graft removal was performed in three (33.3%), complete stent graft removal in three (33.3%), and complete preservation of stent graft in three (33.3%) patients. The mean duration of the operation was 214.7±44.8 min, and the mean amount of intraoperative blood loss was 550±235.7 mL.

Overall postoperative complications and outcomes

Overall, perioperative mortality occurred in one hemodynamically unstable patient operated for aneurysm rupture. One of the patients who presented with rupture died due to acute renal failure and pulmonary complications in the ICU after emergency SC. The 30-day overall mortality rate was 22.2%, and all of these patients underwent late SC in the emergency setting. In addition, one patient required temporary renal dialysis and reoperation due to abdominal wound dehiscence, which required prolonged ICU (five days) and hospital stay (30 days). The median length of ICU stay was 2.2 [1-5] days and the median hospital stay was 10 [4-30] days. The 30-day mortality rate in the emergency group (50%) was higher than in the elective group (0%), although it did not reach statistical significance (p=0.167) (Table 6). No late death was recorded during a mean follow-up period of 21±11.9 months.

DISCUSSION

Since the first successful endovascular AAA repair two decades ago, EVAR has been increasingly preferred as a safe procedure. Although the process of aneurysm removal with EVAR is undoubtedly beneficial compared to surgery in terms of operative mortality, length of hospital stay and recovery, the advantage in early outcomes is not reflected in the long-term outcomes.[9] The Endovascular versus Open Repair of Abdominal Aortic Aneurysm (EVAR-1) trial reported that the early advantages were completely lost in long-term, and it was associated with a higher rate of aneurysm-related complications and mortality at four years after EVAR.[10]

Despite the technological advances, the need for late reintervention after EVAR remains constant and may even increase over time.[11] Although most endograft failures after EVAR are corrected endovascularly, late SC is inevitable in some cases. Therefore, long-term surveillance is essential to monitor stent graft-related complications following EVAR. A recent review reported that late open conversion occurred in 0.4 to 22% of patients undergoing EVAR, with an overall rate of 1.9%.[12] In our cohort, the reintervention rate was 9.1% and late SD rate was 1.02%. Furthermore, as previously reported, endovascular reintervention was attempted in four of nine patients who underwent late SC as a salvage procedure.[13]

Late SC may be indicated for multiple reasons, including endoleak with or without sac expansion, stent-graft migration, rupture and thrombosis, or stent-graft infection.[4] In our series, the most frequent reason for late SC was type 3 endoleak with aneurysm sac expansion, followed by graft migration with sac expansion and rupture. Moreover, four patients presented with more than one indication for conversion, consistent with the literature.[14]

A late SC after EVAR is more challenging than standard elective aortic repair due to periaortic inflammation and fusion of the stent graft to the aortic wall.[4] Various surgical strategies for the management of late SC have been reported, particularly three important points: *(i)* surgical approach, *(ii)* aortic cross-clamping site, *(iii)* stent graft removal options.[15]

Transperitoneal or retroperitoneal approaches can be performed with similar efficacy for surgical exposure of the aneurysm sac, and their use depends on experience and preference of the surgeon.[4] In our study, we performed a midline transperitoneal approach in seven of nine patients and an approach without opening the abdominal wall in two patients with stent graft thrombosis. Based on our experience, the midline transperitoneal approach is the main technique in our clinic.

The site of aortic cross-clamping is another important consideration in the operative management of late SC. Performing proximal aortic cross-clamping as far away from the stent graft as possible allows for better exposure and mobilization of the proximal end of the stent graft.[14] In our study, we preferred suprarenal aortic clamping in four patients and thoracic aortic clamping in one patient. The majority of these patients were operated in the emergency setting. However, infrarenal cross-clamping is advantageous in reducing the risk of renal and visceral ischemic injury.[16] Therefore, it is recommended that proximal aortic cross-clamping should be gradually shifted distally as soon as possible.[17] In two patients with stent graft thrombosis, we were able to correct the complication without aortic clamping after EVAR. In these patients, axillobifemoral bypass and cross-femoral bypass grafting were our treatment of choice to minimize the operative risk.

The decision regarding stent graft management during SC (complete/partial stent graft removal or complete preservation) is still a controversial issue, although it usually depends on the indication for reintervention, the intraoperative condition, and the surgeon's preference. Although some authors have advocated that complete removal of the stent graft is the safest surgical intervention to avoid possible late complications,[15] it has been suggested that explantation maneuvers may increase the risk of intraoperative aortic injury, particularly in well-incorporated endografts.[18] In general, we prefer to perform complete removal of the stent graft only, when late SC is indicated due to graft infection and proximal endoleak, as reported by Forbes et al.[19] However, lifelong surveillance is mandatory due to the risk of late complications from the retained portion of the stent graft.[20] No late complications or mortality were observed in our cohort after late SC.

In the current study, we calculated the cut-off value for the initial aneurysm diameter of ≥66 mm for the need for a second EVAR intervention. Since only one of 98 patients underwent late SC,

no statistically significance can be made for this group. These findings may provide a guide for surveillance programs in patients after EVAR, but more research is needed to investigate this hypothesis. Among all patients who underwent late SC, the 30-day mortality rate in the emergency group was higher than elective group, similar to other series.[4] These findings support the aforementioned observation and also demonstrate the importance of the surveillance program.

Nonetheless, there are some limitations to this study. First, the study has a single-center, retrospective design, which limits the representation ability for the whole population. Second, the small number of patients with late conversion after EVAR in our institute prevented us from drawing statistically significant conclusions. Therefore, further multi-center, large-scale, prospective studies are needed to confirm these findings.

In conclusion, despite technological advances, the need for late reintervention after EVAR remains constant and may even increase over time. Late SC, although rarely necessary, remains a challenging issue after failed EVAR. Elective SC seems to be associated with more favorable outcomes. Late SC in elective cases can be safely and successfully performed before serious adverse events occur. The likelihood of need for reintervention after EVAR is higher in patients with an AAA diameter of ≥66 mm. The surveillance program after EVAR is of utmost importance to ensure that patients do not need urgent conversion, particularly in patients with an initial aneurysm diameter of ≥66 mm.

Ethics Committee Approval: The study protocol was approved by the Dr. Siyami Ersek Chest Heart and Vascular Surgery Training and Research Hospital Ethics Committee (date: 20.05.2016, no: 28001928-051.99). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea, design, data collection, literature review, wrting the article: S.A.; Data collection, literature review, design: S.B.E.; Data collection: M.S.; Control, crtitical review: O.S.; Design, supervision, critical review: E.K.; Supervision, critical review: S.A.A.

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